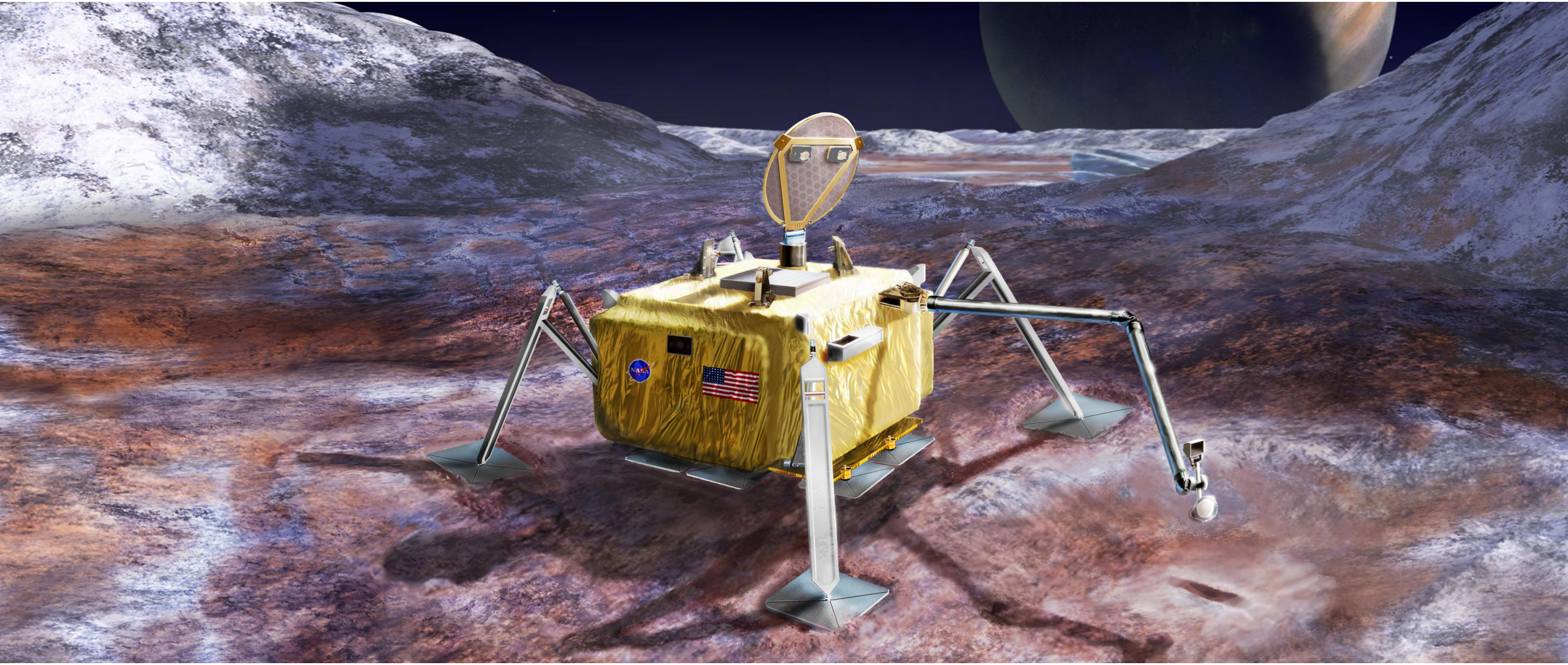


Europa Lander Overview and Update

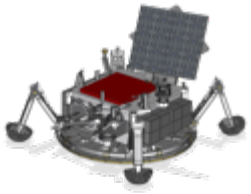
Steve Sell

16th International Planetary Probe Workshop, Oxford, UK

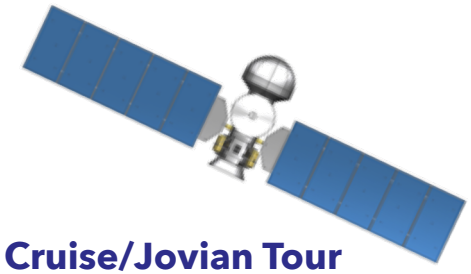
June 2019

Jet Propulsion Laboratory
California Institute of Technology

Europa Lander Mission Concept as of delta-MCR (Nov. 2018)

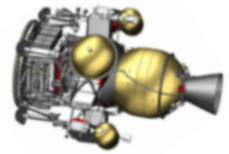


Launch
- SLS Block 1B

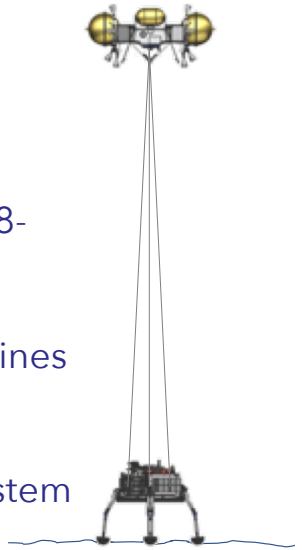


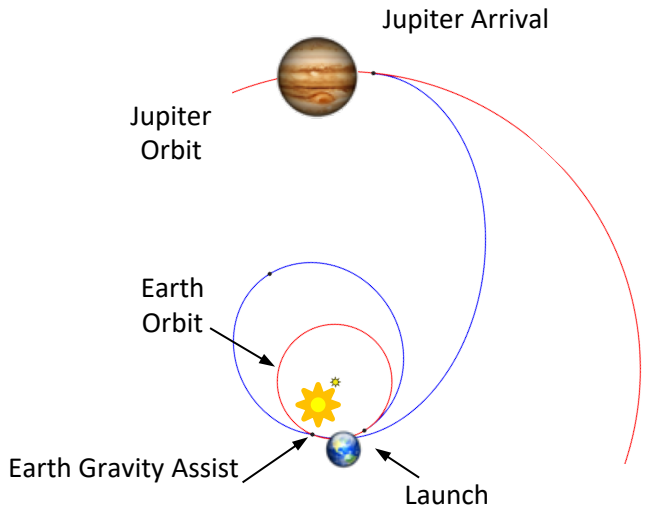
Cruise/Jovian Tour
- Jupiter Orbit Insertion: L+4.7 hrs
- Europa Landing: JOI+2 yrs

Carrier Stage
- 1.5 Mrad radiation exposure
- Elliptical disposal orbit

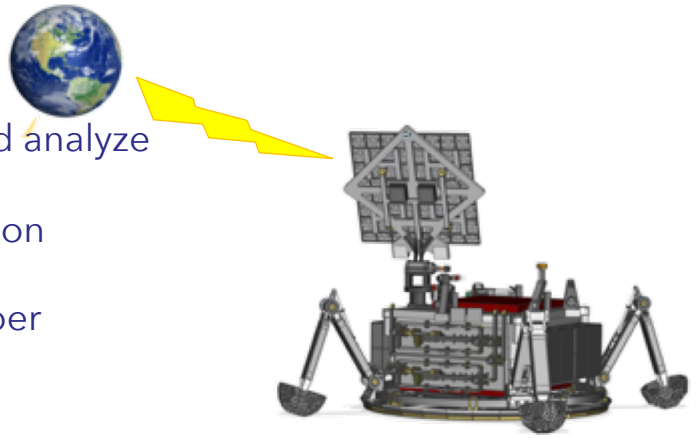


Deorbit, Descent, Landing
- Guided deorbit burn w/ Star-48-class solid rocket motor
- Sky Crane landing system
- 800N throttleable MR-104 engines
- 100-m accuracy
- 0.1 m/s velocity knowledge
- Terrain-conforming landing system



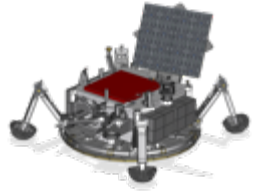


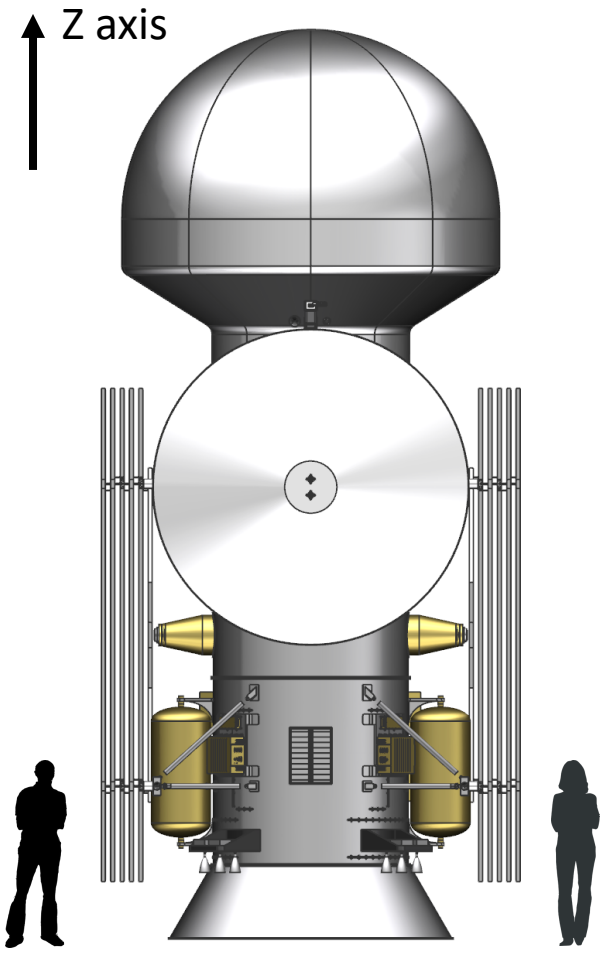
Surface Mission
- Biosignature Science
- Excavate to 10cm, sample, and analyze cryogenic ice
- 22 days surface mission duration
- High degree of Autonomy
- Direct to Earth Comm or Clipper (contingency)
- 1.5 Gbit data return
- 2.0 Mrad radiation exposure
- Terminal Sterilization for PP



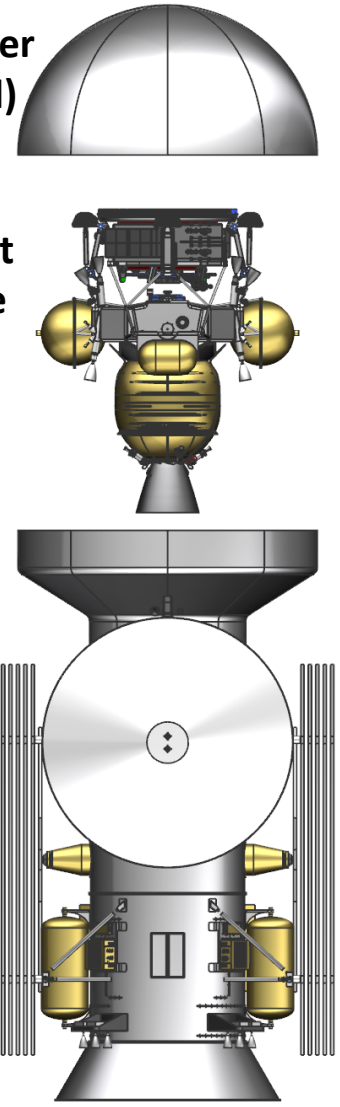
Concept Drawings

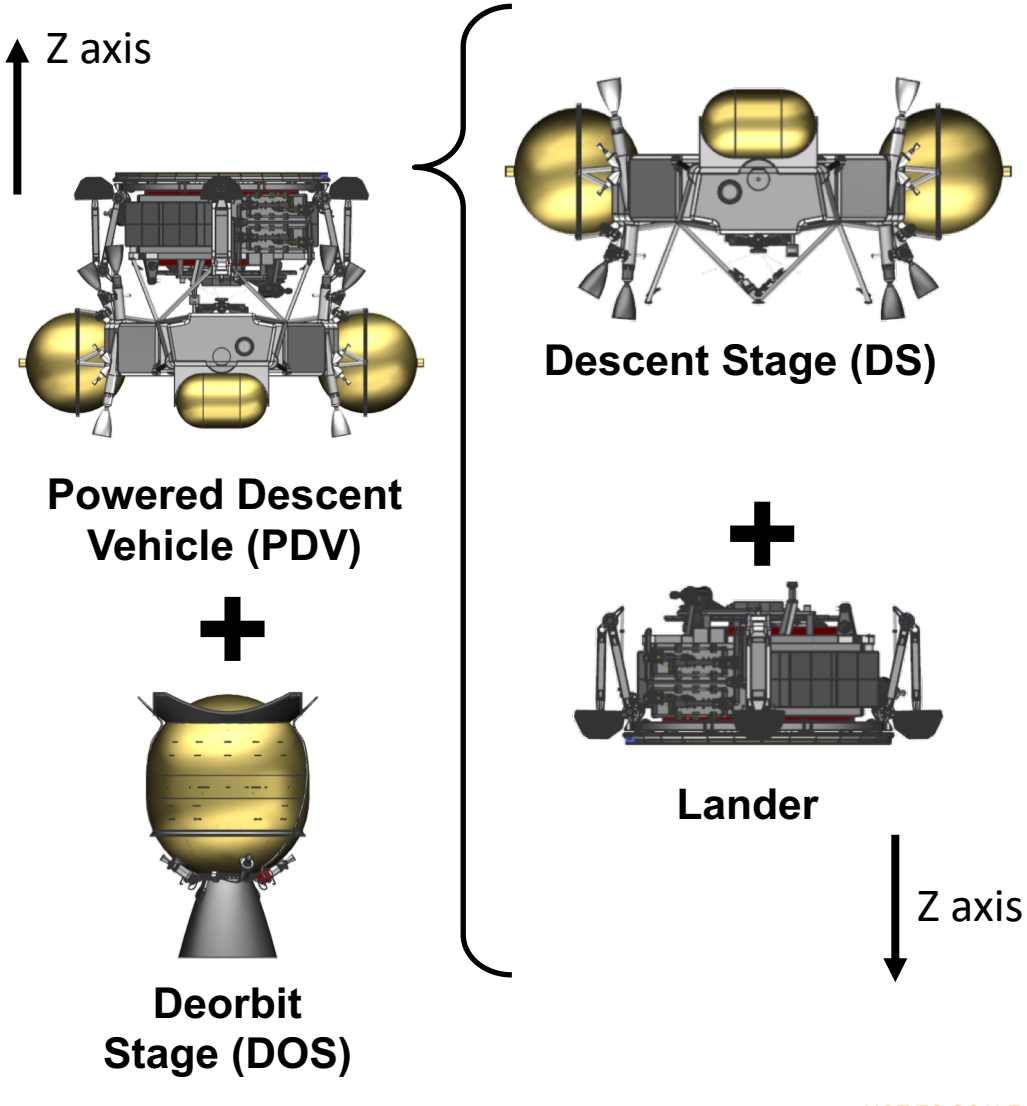
Baseline Flight System Vehicles





Launch Mass: ~15-16 mt

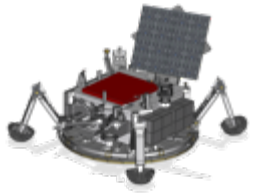




Concept Drawings

NOT TO SCALE

Baseline Deorbit Vehicle Configuration and Events



GNC Sensors Pod
- LIDAR
- LVS camera
- ILS computation
- Star Tracker
- IMU

Descent LGA

8x Throttled Descent Engines

He Pressurant Tank

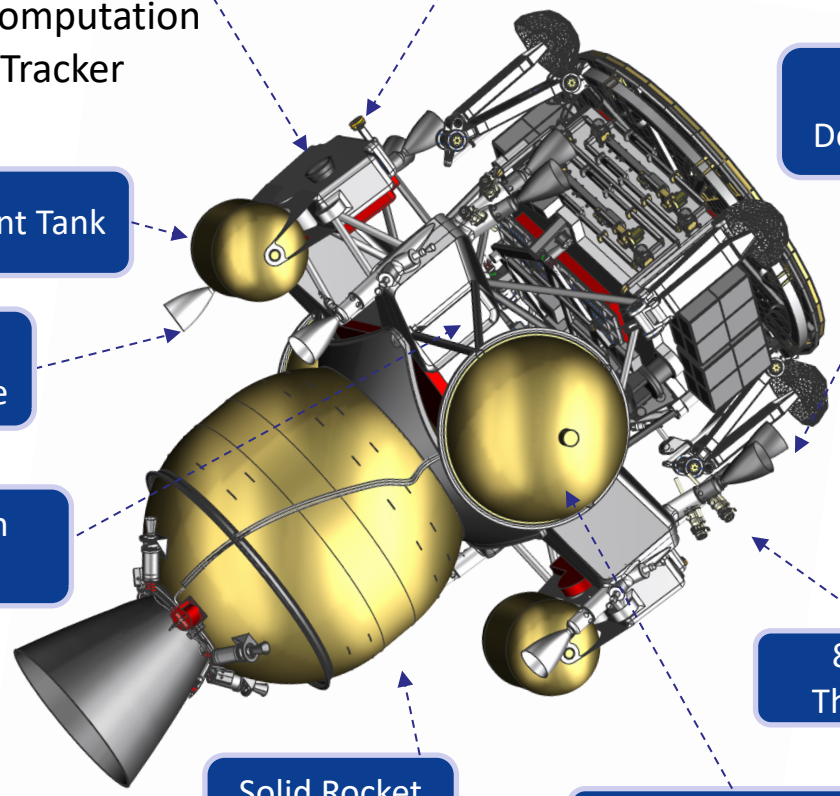
4x Pulsed TVC Engine

DS Main Vault

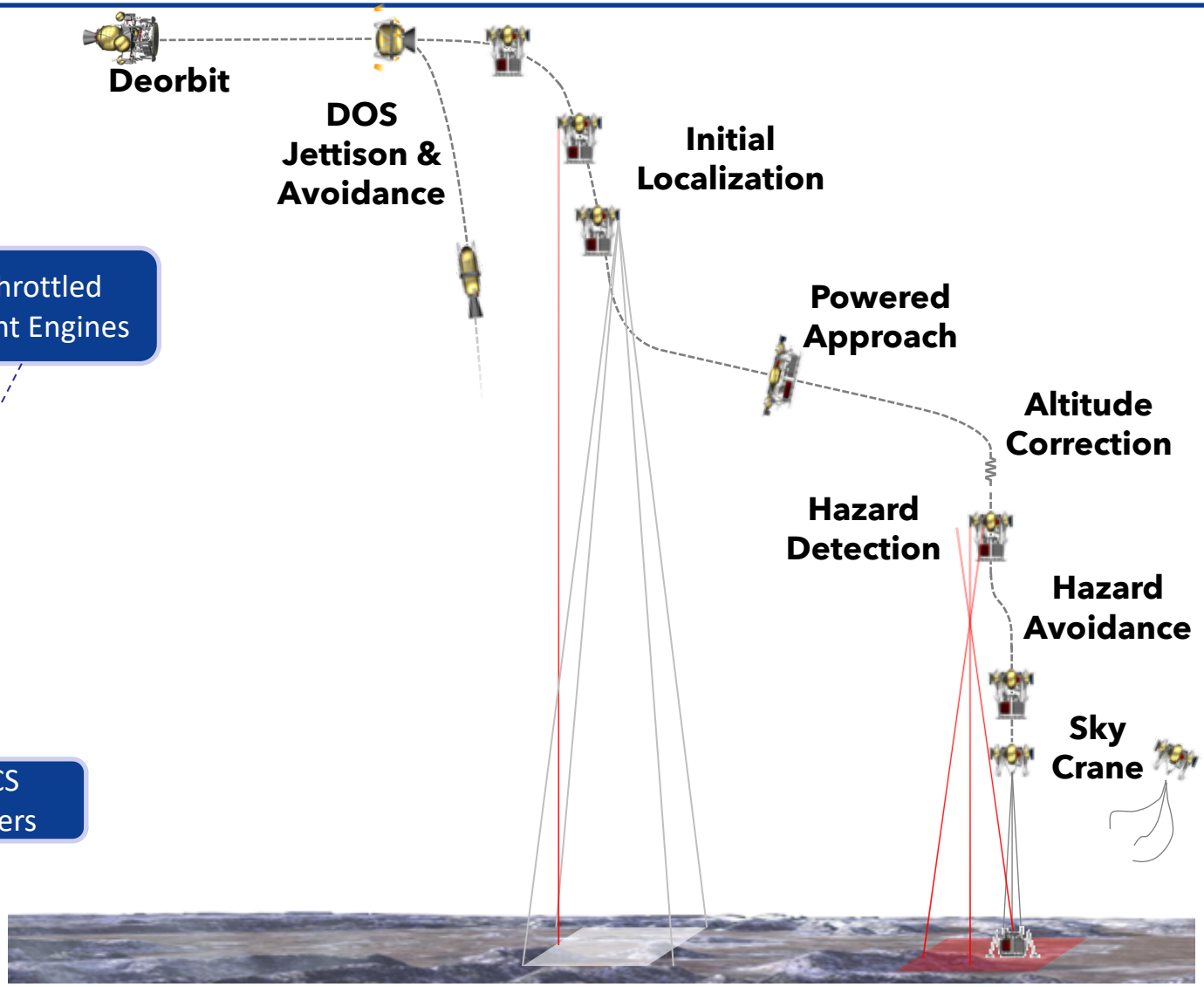
8x ACS Thrusters

Solid Rocket Motor

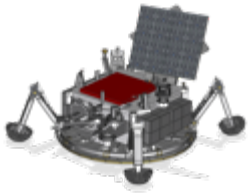
Hydrazine Tank

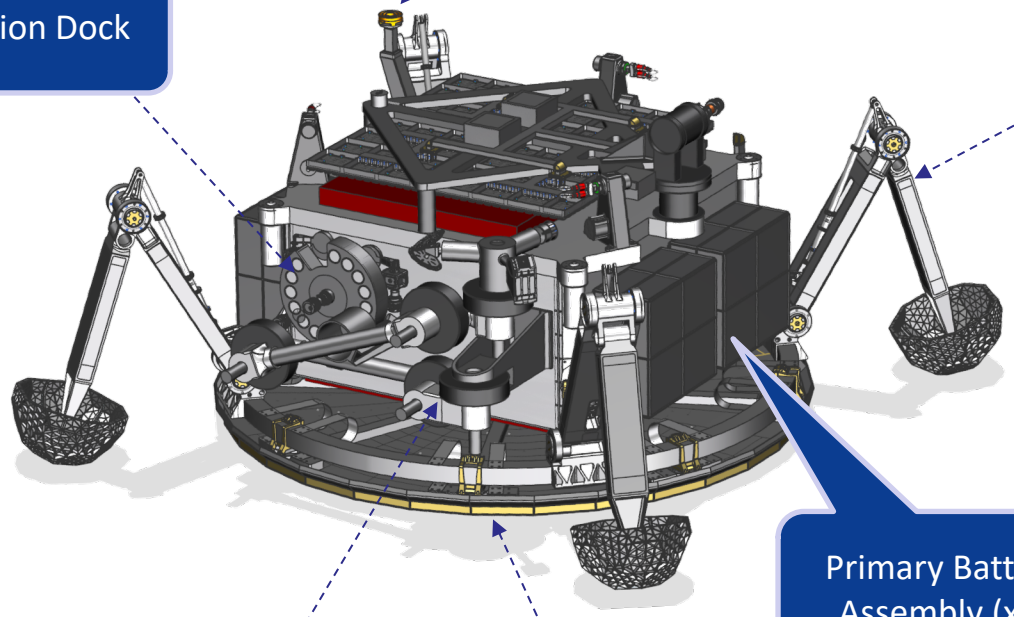


Concept Drawings



Baseline Lander Stage Configuration





Low Gain Antenna

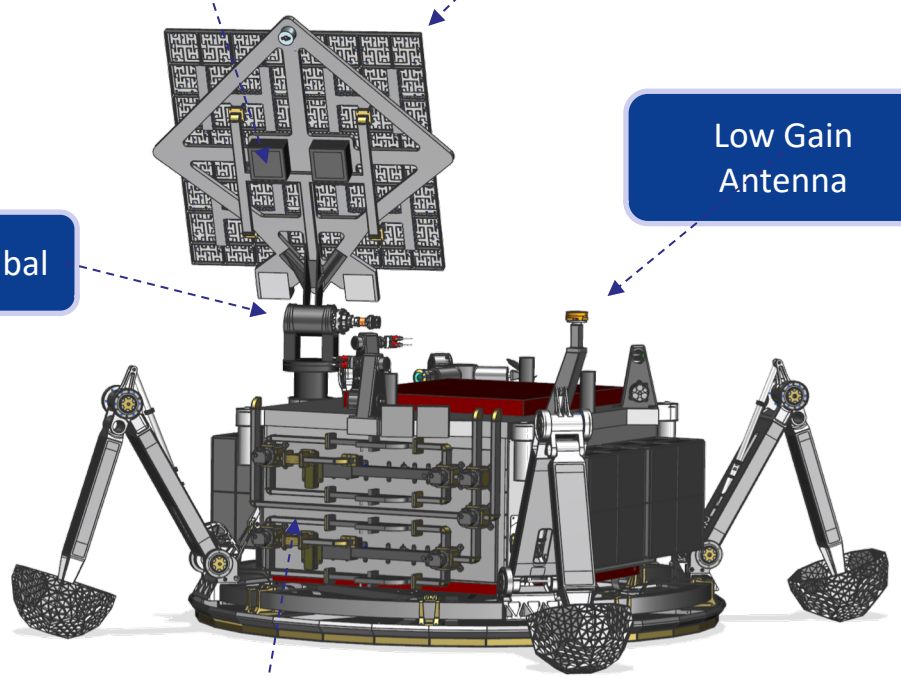
Collection Dock

Adaptive Stabilizers (x4)

Primary Battery Assembly (x4)

Robotic Arm (5 DoF) with end effector collection tools

Belly Pan



Stereo Context Cameras (x2)

High Gain Antenna

Low Gain Antenna

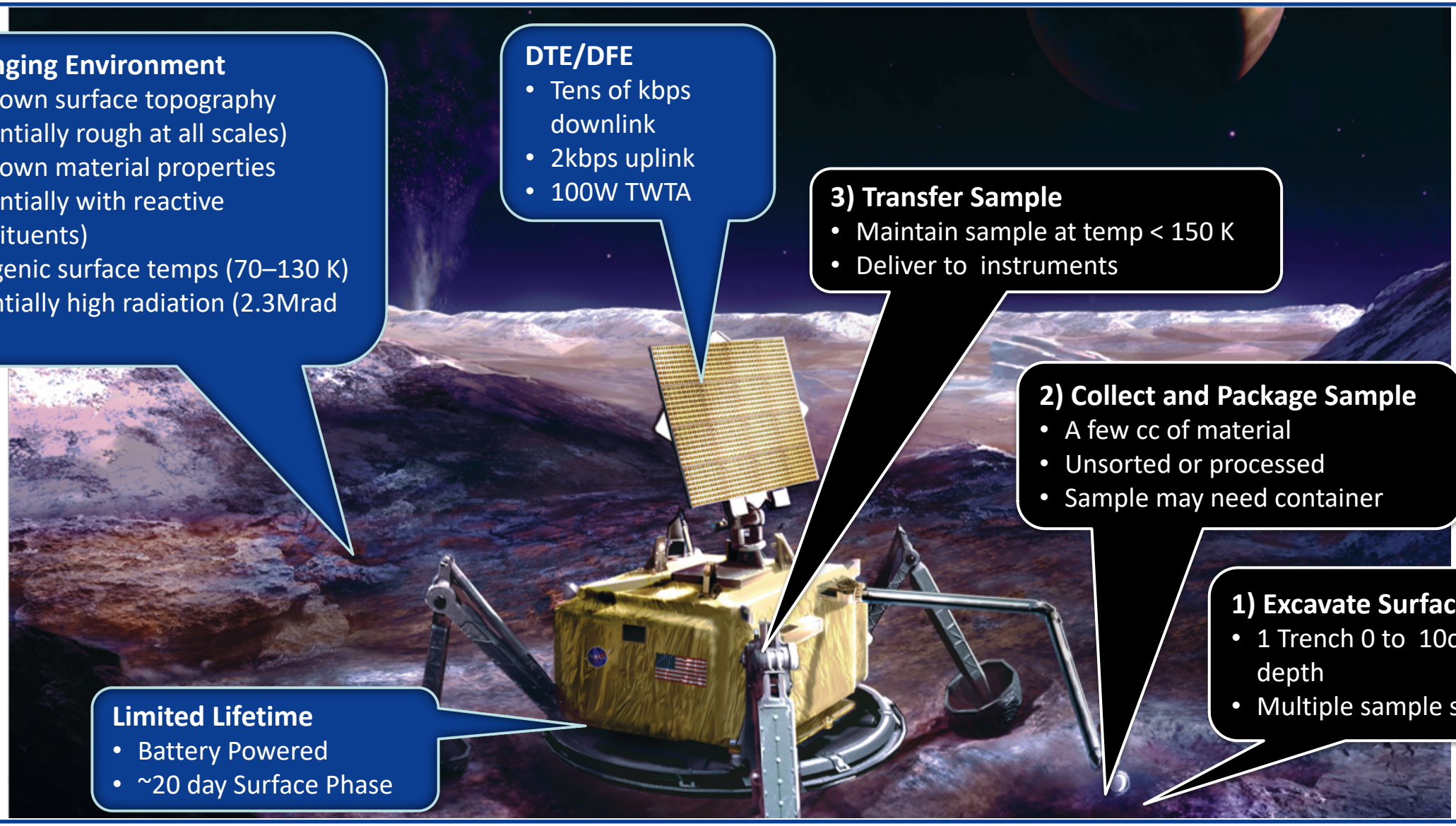
2-axis Gimbal

Footpads (x4)

Radiation Protected Vault

Concept Drawings

Surface Mission Concept Challenges



Challenging Environment
- Unknown surface topography (potentially rough at all scales)
- Unknown material properties (potentially with reactive constituents)
- Cryogenic surface temps (70–130 K)
- Potentially high radiation (2.3Mrad TID)

DTE/DFE
- Tens of kbps downlink
- 2kbps uplink
- 100W TWTA

3) Transfer Sample
- Maintain sample at temp < 150 K
- Deliver to instruments

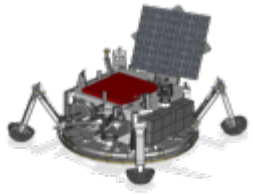
2) Collect and Package Sample
- A few cc of material
- Unsorted or processed
- Sample may need container

1) Excavate Surface
- 1 Trench 0 to 10cm depth
- Multiple sample sites

Limited Lifetime
- Battery Powered
- ~20 day Surface Phase

Concept Drawings

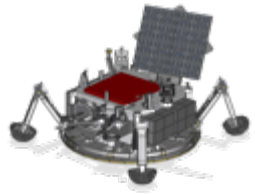
Not Typical Mars Experience

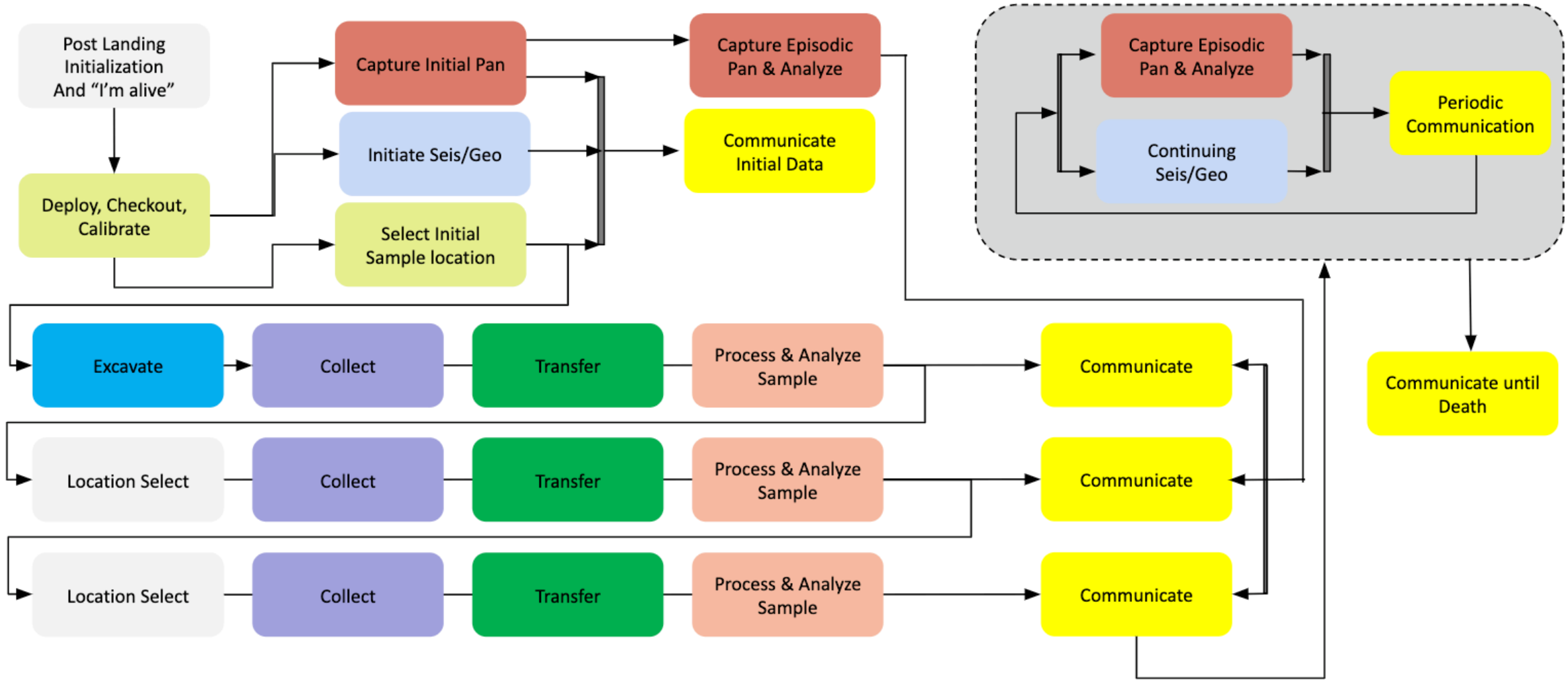


- Data pipe is much smaller – this ocean world is a lot farther away
- There may be no environmental advantage to day or night
- Lander scale knowledge of the surface will not be known until we arrive
- Very different contact frequency
  - Mars: UHF relay twice a day for short durations at high data rates (up to 1 Mbps)
  - Europa Lander: 36 hrs DTE while earth in view at very low data rates (~tens of kbps), 36 hours of no communications,
- Radiation effects may disrupt electronics
- Lifetime is always slipping away - No power generation, primary batteries only
  - Flexibility isn't as important as lifetime
- Cannot afford a ground directed operations strategy that isn't optimized for limited lifetime
  - GITL time to decide, deduce, plan, react, contemplate – all cost lifetime
  - Autonomy, self-reliance and efficiency enable success in the limited lifetime

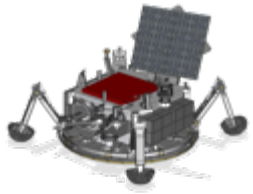
Successful mission in 20+ days is beyond our Mars in-situ mission experiences: we have to be different

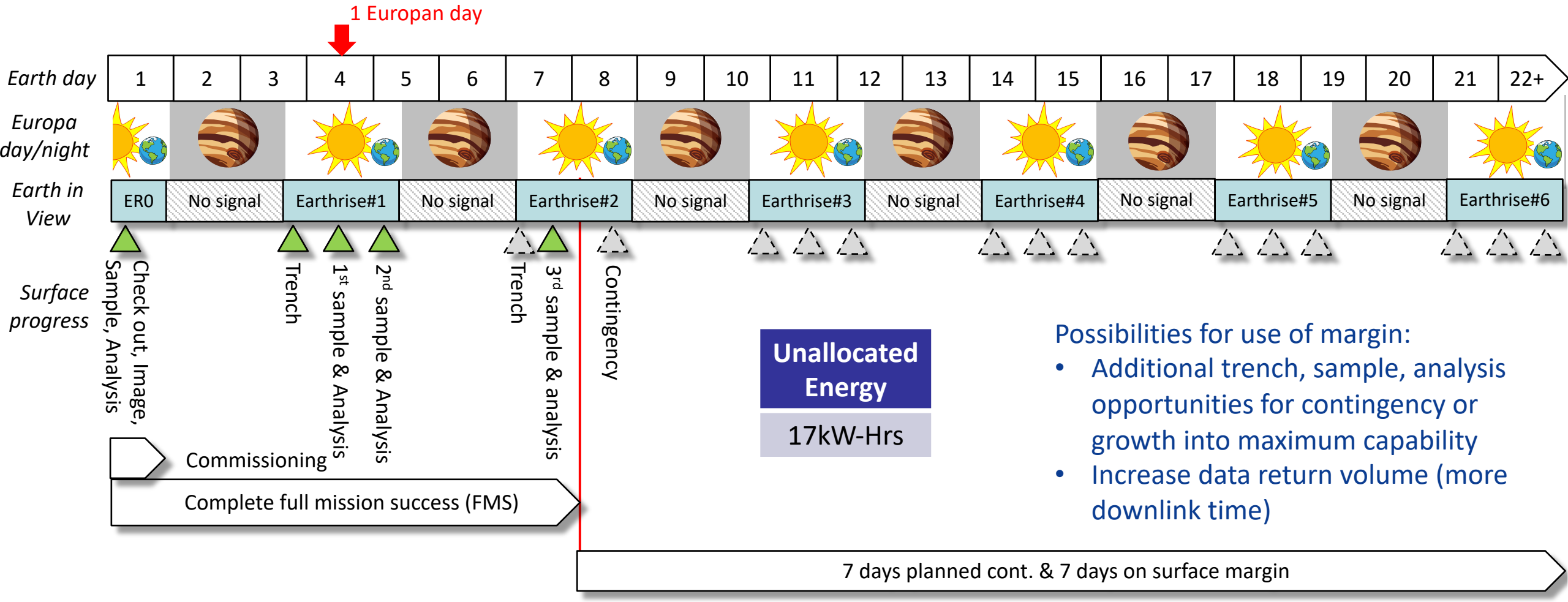
Basic Surface Reference Mission





Energy & GITL Sizing Timeline





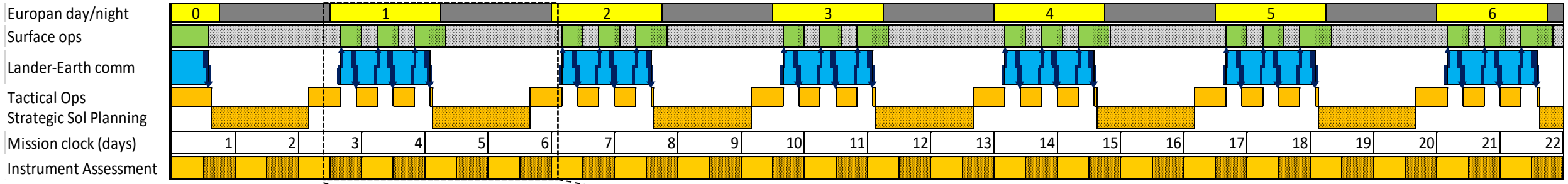
Unallocated Energy

17kW-Hrs

Possibilities for use of margin:

- Additional trench, sample, analysis opportunities for contingency or growth into maximum capability
- Increase data return volume (more downlink time)

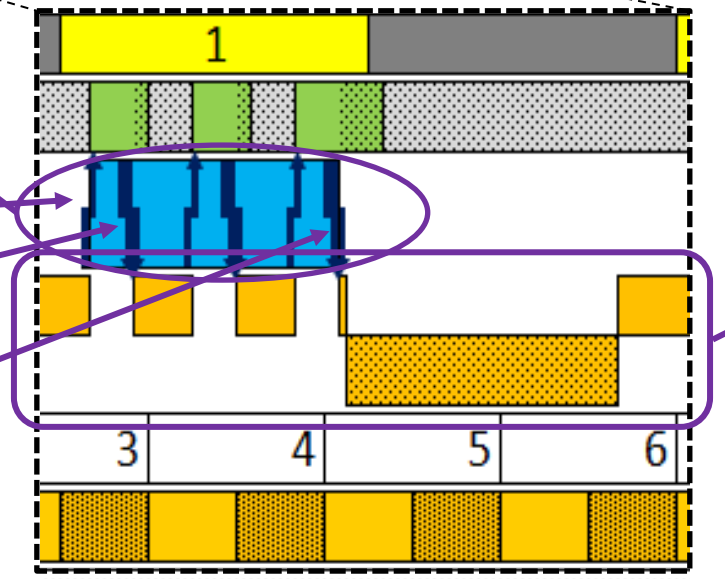
Use Case for Ground-in-the-Loop Operations



36 hours of communications available only when Earth in view

Example Use Case for design:

- Start each Earth-in-view (EIV) period with an uplink opportunity
- Downlink when critical data is ready for transmission
- Downlink vehicle and plan status before EIV period ends
- Additional opportunities for uplinks to adjust plan within EIV



One Europan Sol Commanding Opportunities

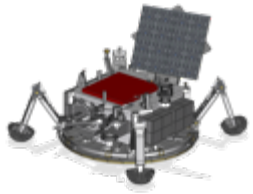
Opportunities for Ground-in-the-Loop (GITL) supports long periods of strategic planning alternating with short bursts of tactical planning

Ground Ops durations envelop variations in surface scenarios

- 8 hours tactical
- 24 hours strategic

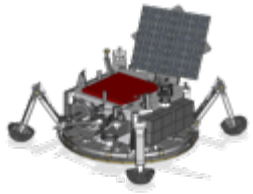
OWLT = ~45 min

Europa Lander Status



- Europa Lander pre-Project status
  - Held delta-Mission Concept Review (MCR) in Nov. 2018
    - "The review board [chaired by Bobby Braun] cannot recall a pre-phase A planetary science concept at this advanced level of fidelity"
  - FY19 budget signed, but near-term budgets unlikely to include funding levels required for new start
- NASA selected 14 potential instruments for maturation under Instrument Concepts for Europa Exploration 2 (ICEE-2) @ ~$2M each for 2 years
  - Funded out of FY18 budget
- High-priority Advanced Development maturation tasks have begun
  - Reduces flight development risk
  - Many tasks applicable to projects beyond Europa Lander

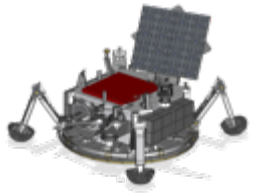
Advanced Development Activities



- Update launch opportunities and perform flight system impact assessment
  - Launch Period Survey and Interplanetary Trajectories
  - Navigating 3-body arrival with a short period
  - Support to Clipper Reconnaissance Focus Group
  - Assess DDL/Nav trade space

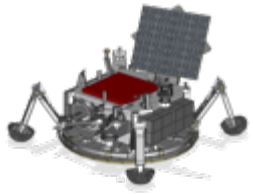
- De-orbit, Descent, and Landing (DDL)
  - DDL sensors
    - Reduce sensor hardware and algorithm development risk
  - Landing
    - Prototype and test landing system (legs, feet, bellypan) concepts for very rugged terrain
  - Propulsion
    - Prototype and test low-thrust throttleable engine
    - Environmentally test solid rocket motor propellant and ignition system

Advanced Development Activities



- Surface
  - Sampling
    - Prototype and environmentally test excavation, acquisition, and sample transfer techniques
      - Interact with ICEE-2 selectees to conduct rapid-prototype evaluation of interfaces
    - Develop approaches to maintain samples <150K
  - Autonomy: Develop and test concepts for highly autonomous operations
    - Develop software simulation and hardware testbed for development of autonomy designs
    - Mature autonomy sensing, closed-loop control, and computational requirements
  - Resources (size/weight/power/life/computation)
    - Develop and test lightweight, low-power motor controller
    - Continue radiation and life testing of primary batteries
    - Develop and test full-scale High-Gain Antenna
  - Planetary Protection/Contamination Control
    - Conduct planetary protection/bioburden analyses to mature payload and flight system requirements
    - Continue development of Terminal Sterilization System
    - Evaluate outgassing properties of radiation-exposed materials
    - Assess plume product interaction and alteration with cryogenic ices

Conclusion



- Europa Lander pre-project has successfully completed its Mission Concept Review
  - Funds availability and near-term NASA budget unlikely to support a project start
- NASA funded Instrument Concepts are helping the pre-project and prospective instrument developers to learn the “tall poles” in instrument accomodations
- Pre-project is taking advantage of healthy Flight System maturation funds to perform development tasks
  - Funding is allocated and secured for multi-year maturation effort